Report to Honorable Board of Directors
of the SCVWCD on

Laboratory and Field Investigations
of
Water Clarification by Chemical Means

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REPORT
TO THE
HONORABLE BOARD OF DIRECTORS
OF THE
SANTA CLARA VALLEY WATER CONSERVATION DISTRICT
ON
LABORATORY AND FIELD INVESTIGATIONS
OF
WATER CLARIFICATION BY CHEMICAL MEANS

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I. INTRODUCTION

A number of chemical coagulants has been evaluated in the District laboratory and two chemicals have undergone field testing. This report is being prepared, therefore, to summarize the results of these tests by listing coagulants, describing some of the testing procedures, and by the interpretation of data. Cost estimates of chemical treatment, based on laboratory results, have been computed to evaluate the various commercial products. Finally, some conclusions are submitted regarding the practicability of the District water clarification program.

II. HISTORY

The District has long been aware of damage to percolation ponds from sediment laden waters directly following a storm. These waters are generally not accepted into percolation ponds for several hours following a storm, or until the water drops its silt load. In order to accelerate the natural sedimentation processes, the District has been investigating the feasibility of using a chemical means of coagulating and settling turbidity.

A chemical coagulant was first utilized by the District with the help of Dow Chemical Company. Using a Dow product called Separan AP30, a series of field tests was run. The initial tests were conducted at Main Avenue percolation ponds. The results of these tests were published in a report by Dow Chemical Co., dated April 21, 1959. A similar test, which was of operational duration, was conducted during July, 1960 in Stevens Creek. Some experimental work was also done in Penitencia Creek in the spring of 1962. It can be said of these tests that flocculation did occur and water clarity was improved, but the results must be called inconclusive due to a lack of measuring criteria such as absolute turbidity changes, hardness, and pH.

Following the storm of October, 1962, further field tests were conducted using Separan AP30 in Los Gatos Creek. A settling basin was constructed in

Lahey Percolation Pond #3. This experiment did not yield satisfactory results. While some flocculation was apparent, the over-all turbidity of the water was not appreciably reduced.

It was at this time that the District decided to adopt a more scientific approach to a water clarification program. To help initiate this program, Mr. Dave Caldwell (of Brown & Caldwell, Chemical Engineers) was called upon to consult with the District staff on the morning of Oct. 22, 1962. He outlined procedures and recommended various equipment for initiating a laboratory. One of Brown & Caldwell's staff, Mr. Les Dunlap, worked with us on October 26, 1962, to help establish correct laboratory procedures such as running jar tests, measuring turbidity, and recording data.

III. LABORATORY COAGULATION TESTS

During November and December, 1962, laboratory jar tests were completed on a number of commercial coagulants and coagulant aids. These jar tests were run on a standard 6-jar laboratory stirring apparatus. Uniform mixing times of 5 minutes @ 40 R.P.M. and settling times of 30 minutes, were established as bases for comparison of the chemicals. Those chemicals that showed the greatest coagulating abilities, under the imposed conditions, were given the more thorough testing. Listed below are the chemicals that have been tested in the laboratory.

1. Separan AP30 is a coagulant, produced by Dow Chemical Co., described as a high molecular weight synthetic polymer. It is an anionic polyelectrolyte in neutral solutions. It is a slow dissolving (in water), powdered solid.
2. Separan NP10, by Dow Chemical Co., is described as a high molecular weight synthetic polymer, essentially nonionic in solution. It is a slow dissolving, powdered solid.
3. Separan NP20, by Dow Chemical Co., is described as a high molecular weight synthetic polymer.

4. Nalcolyte 110, produced by Nalco Chemical Co., is described as a high molecular weight complimentary coagulant. It is in powder form and is quite low in density (9 lbs/cu.ft.).

5. Nalcolyte 670, by Nalco Chemical Co., is a flocculant described as a polyacrylamide polymer of high molecular weight. It is a powdered solid, with a density of 43 lbs/cu.ft., which dissolves with extreme difficulty in water.

6. Nalco 600, by Nalco Chemical Co., is a coagulant described as a cationic polyelectrolyte of high molecular weight. It is produced in liquid form with a weight of 9.0 lbs./gallon.

7. Nalcolyte 605, produced by Nalco Chemical Co., is a high-activity cationic liquid polyelectrolyte coagulant. This amber-colored liquid closely resembles Nalco 600, but is more highly cationic.

8. Liquid Alum Solution. The commercial grade was used. It is a solution of 5.5 pounds of dry alum, $Al_2(SO_4)_3 \cdot 18H_2O$, per gallon of water. Alum has wide usage as a primary coagulant in the water works industry.

9. Alum. A commercial grade of alum crystals, $Al_2(SO_4)_3 \cdot 18H_2O$, was tested. The sample tested was from the Chemical Division of North American Coal Corporation.

10. Slaked lime, $Ca(OH)_2$ was used to pre-treat water, in a number of tests prior to the addition of a coagulant.

The above listed chemicals were tested on waters of varying turbidities from Los Gatos, Guadalupe and Penitencia Creeks. Some tests were conducted with a single coagulant being used, while other tests were run with two or more chemicals in combination. To best evaluate these chemicals as to their versatility and effectiveness, certain criteria were established. These criteria are listed on the following page:

1. "Floc" Formation - Each chemical's ability to coagulate waters of varying turbidities was determined. Under this category, the dosages required to form visible "flocs" were recorded.
2. Minimum Mixing Time - The time of mixing was judged an important criterion. Rapid reaction of the chemical with suspended solids is paramount in locations such as Upper Page Ditch and Penitencia Creek due, in each instance, to a short available length of canal prior to the settling pond.
3. Minimum Settling Time. An important consideration, in the design of desilting basins, is the settling time required for the chemically treated water. More rapid settling rates enable the construction of smaller settling basins and increases the capacities of existing ponds.
4. "Floc" Stability. The stability of flocs is considered important. Turbulence after floc formation can disrupt the coagulated matter and increase final turbidities of the treated water. In the field, turbulence can be caused by a drop structure in a canal or increased velocities in culverts.
5. Wide pH Range. Ability of coagulation over a wide range of pH was tested, although the natural runoff waters exhibited pH in the narrow range of 7.8-8.3.
6. Effectiveness in Soft Water. Hardness, as ppm $CaCO_3$, was determined for most water samples, because of the inability or difficulty that most coagulants exhibited in treating soft water. Hardness was, therefore, deemed an important consideration, as local storm runoff water is generally low in hardness.
7. Efficiency of Flocculant.

$$\text{Efficiency (as a percentage)} = \frac{\text{Initial turbidity} - \text{Final turbidity}}{\text{Initial turbidity}} \times 100$$

IV. EVALUATION OF CHEMICAL COAGULANTS

1. Separan Chemicals - The most extensive group of tests was conducted on the Separan series: AP30, NP10 and NP20. A quantity of AP30 had been purchased for field testing, and since 1959 the District has accumulated experimental data on its use. Recent laboratory testing, however, has better established the limits of usefulness of this coagulant for District purposes.

   Laboratory tests were made, using Separan on water samples from Lexington and Guadalupe Reservoirs. The tests revealed Separan to be ineffective in flocculating this turbid water. This ineffectiveness has been attributed to the low hardness (95-105ppm, $CaCO_3$) of the samples. Further testing revealed, however, that Separan AP30 could build up successful flocculation if the samples were pre-treated for five minutes with a quantity of slaked lime, $Ca(OH)_2$. It is believed that the presence of the Ca++ ion reduced the "Zeta Potential" (the force that prevents sedimentation) of the colloidal particles sufficiently to allow the Separan to coagulate and settle the turbidity.

   No field tests were conducted using lime and Separan in combination, as the large quantities of lime required (300 lbs./acre-foot) were impractical to handle and dispense.

2. Liquid Alum - Liquid alum, consisting of 5.5 pounds of dry alum per gallon of water, is widely used in municipal water treatment plants. An advantage of this chemical is that a great deal of experimental data has been written on its flocculation characteristics. Basic mechanical and chemical reactions, related to alum, are thoroughly understood.

   A number of jar tests was performed using alum as a coagulant. Good flocculation and low final turbidity was achieved on many tests.

Alum was the only chemical tested that would effectively treat waters with turbidities less than 50 ppm.

There are certain drawbacks to the use of alum in the District water clarification program. The "flocs" that are characteristic of alum water treatment are very slow to settle. The required settling times were greater than 30 minutes which was considered a maximum allowable detention time in the settling basin design. Furthermore, alum flocs are relatively unstable and would be broken up from turbulence in the District settling basins as they are presently constructed. Alum is corrosive to ferrous metal and must be stored in Fiberglas or polyethylene-lined tanks.

3. Nalco Chemicals - Nalcolyte 110, 605, 670 and Nalco 600 were each tested in the District laboratory. The Nalcolyte 110 and 670 (both are powdered solids) did not exhibit the versatility of Nalco 600 and Nalcolyte 605. These latter two chemicals are amber-colored liquids, which closely resembled each other in their respective tests. On test samples from Los Gatos and Guadalupe Creeks, Nalco 600 produced slightly lower final turbidities over a range of chemical dosages from 2-10 p.p.m.

A limited number of tests conducted on Penitencia Creek water yielded somewhat different results. The turbidity in this storm water coagulated quite easily with several of the chemicals tested. The suspended material in the water was far less stable than the Los Gatos and Guadalupe Creek samples and the water would settle clear in about 24 hours without chemical treatment. The hardness of this runoff water was the highest of any tested (about 290 ppm, $CaCO_3$). On this Penitencia Creek water, Nalcolyte 605 was clearly superior to Nalco 600. Nalcolyte 670 was also used successfully, with good results with dosages as low as 0.1 p.p.m.

V. SUMMARY OF SUCCESSFUL COAGULATION TESTS:

Coagulants & Coagulant Aids	Dosage Lbs/AF	Chemical Cost/AF	Remarks
Separan AP30 + Lime $Ca(OH)_2$	1.0 300	3.75 1.25 5.00	In the field use of this chemical treatment, a logistics problem would be created in handling and dispensing large quantities of dry lime.
Liquid Alum Solution	270	10.80	The alum-formed flocs are small and light; they may not be stable enough for the relatively turbulent conditions of the District settling ponds.
Nalco 600	14	4.45	The chemical's corrosiveness to non-ferrous metals makes it more difficult to handle and dispense.
Nalcolyte 605	14	4.80	On the waters tested, this chemical exhibited equal coagulating ability to Nalco 600.

General Notes:

1) The above listed dosages, under laboratory conditions yielded final turbidities of 25± p.p.m.
2) The above dosages are average values, varying with hardness but relatively independent of turbidity.
3) Water from Penitencia Creek was not available for sufficient time to allow adequate sampling and testing. The above listed dosages may not be optimum for coagulation of this water.
4) Alum was the only coagulant that could clarify water of low turbidity (50 ppm) due to the action of $Al(OH)_3$ precipitate.
5) Chemical costs used: Lime: $25.00/ton
Liquid Alum: 80.00/ton
Separan AP 30: 1.25/lb.
Nalco 600: 0.318/lb.
Nalcolyte 605: 0.342/lb.

VI. FIELD TESTING NALCO 600

The versatility of Nalco 600 and its low estimated cost, resulted in a field test conducted on Los Gatos Creek water from December 10 to December 12, 1962. Two 55-gallon drums of this chemical, diluted to 3% by weight in water, were used during this 2½ day test. This field application was conducted at the Lahey Desilting Pond. Nalco 600 was injected into Kirk Ditch at the headgate and allowed to mix during the 685 foot conveyance to the settling basin. Average mixing time, with a ten cubic feet per second flow, was five minutes.

This test resulted in diminution of turbidity from 250 ppm at the headgate to 35 ppm at the pond discharge. Floc buildup began about 200 feet downstream from the point of chemical application, and floc size increased to a maximum after 600 feet of mixing. The minimum dosage required for this treatment was 2.7 ppm.

VII. CONCLUSIONS

Laboratory and field experiments illustrate that the District can successfully operate a water clarification program. Highly turbid storm runoff that has previously wasted into San Francisco Bay can be salvaged, with a suitable chemical coagulation and settling, for use in off-stream percolation areas. The total cost of this water clarification program, including chemicals, equipment, operations and maintenance would approximate $6.00* per acre-foot of salvaged water.

Before validating the economic feasibility of chemically treating this storm water, a cost comparison must be made with the additional cleaning costs involved in using this turbid water in District percolation ponds. Also, any other means of cleaning this water should be investigated.

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* This cost is based on the use of Nalco 600 as the chemical coagulant.